



Pilot Tests of Adsorptive Media Arsenic Treatment Technologies in the Arsenic Water Technology Partnership



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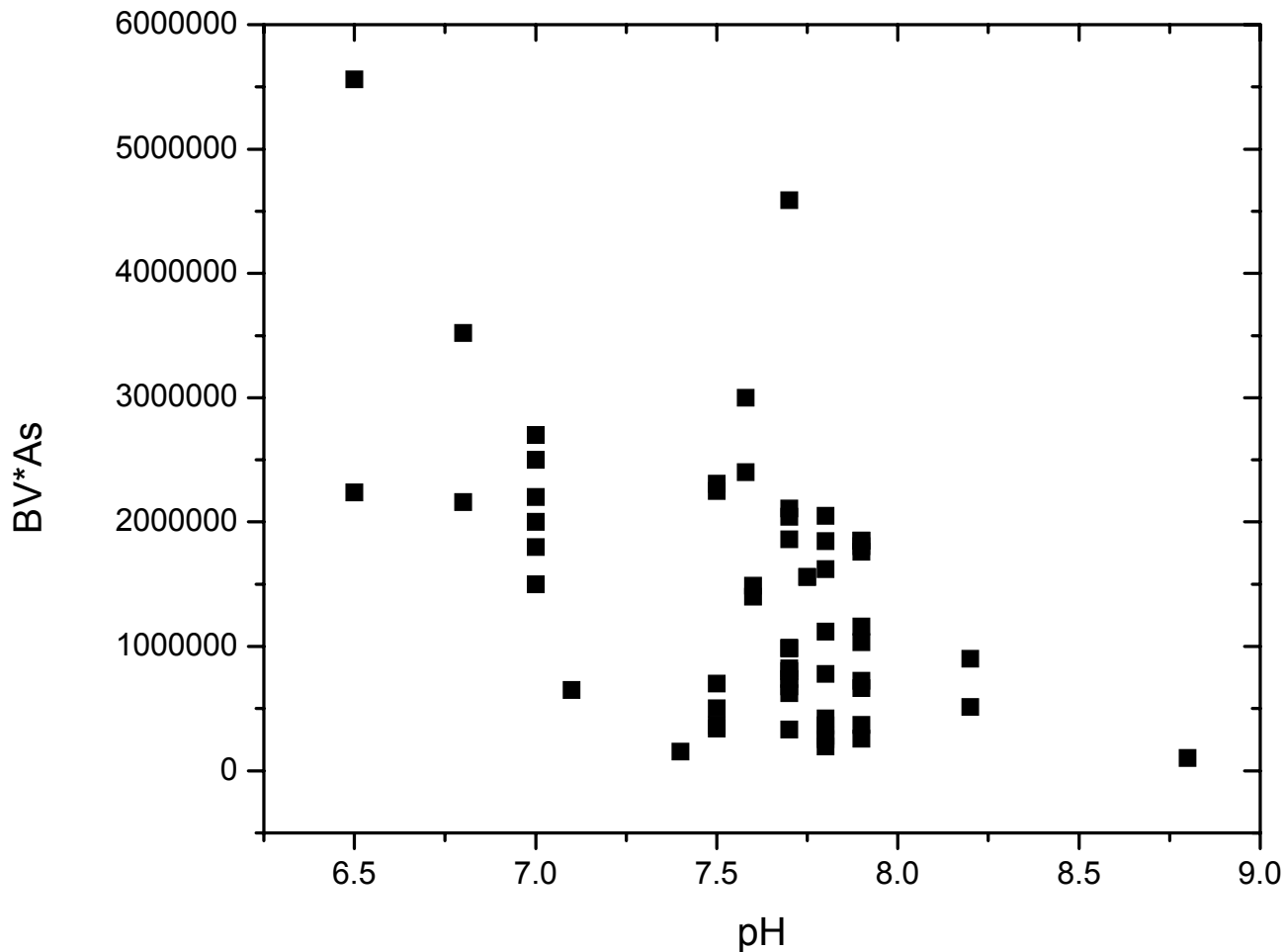
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Why Is Sandia Pilot Testing?

Scatter plots of BV*As vs. pH and SiO

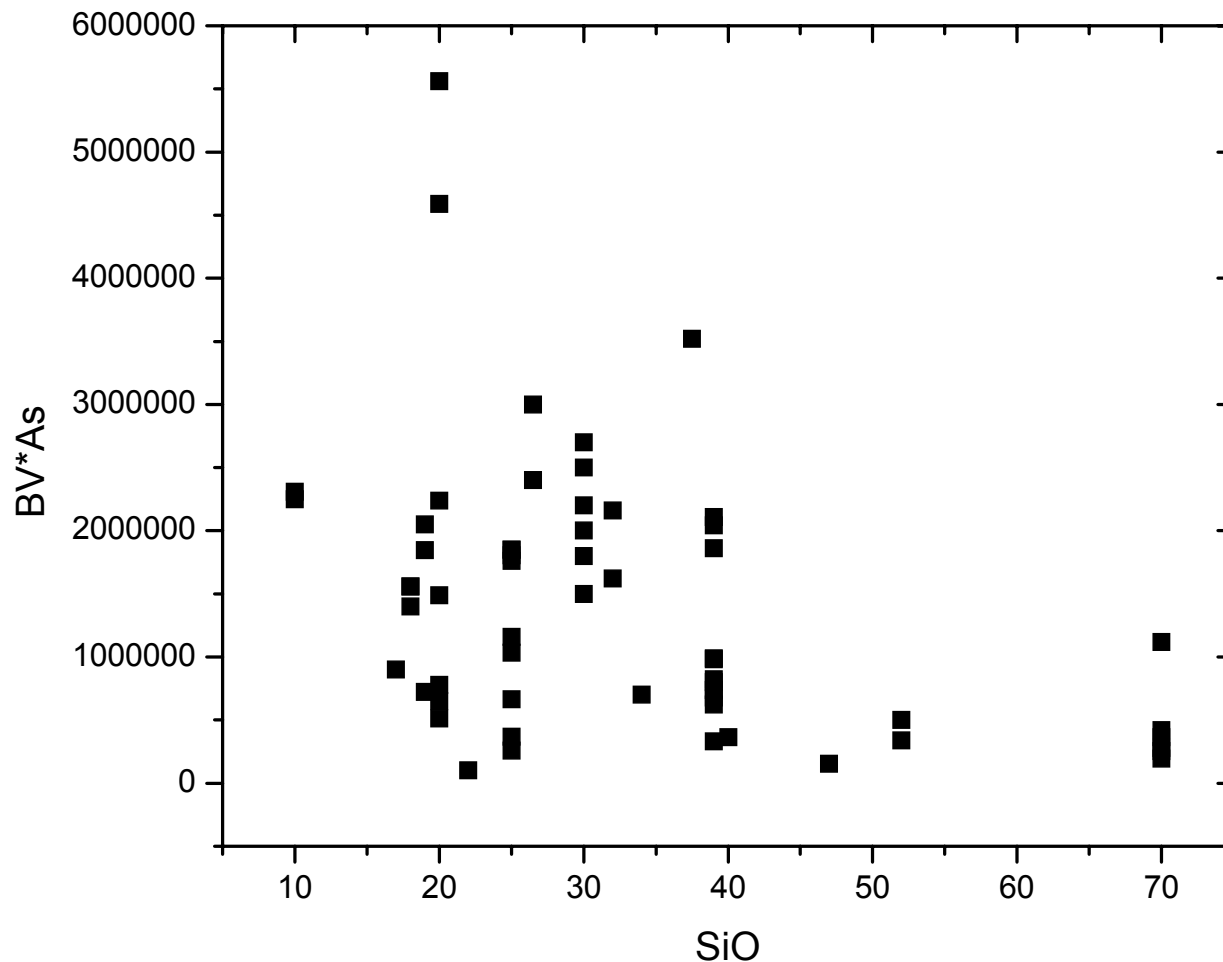


Note: these contain data from various sources, including pilot and RSSCT studies



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Scatter plots of BV*As vs. pH and SiO



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Outline

- **The Arsenic Water Technology Partnership**
- **Site selection**
- **Concepts for Pilot Demonstration Tests**
- **Initial Tests in New Mexico**
 - Socorro, Anthony, Rio Rancho
- **Future work**
 - Jemez Pueblo, Socorro (Phase 2), Oklahoma
- **Summary**



Arsenic Water Technology Partnership Background

- **Congressional Appropriation - \$10M FY03 – FY05**
- **DOE- funded peer-reviewed, cost-shared research program to develop and demonstrate innovative technologies for removal and disposal of arsenic from drinking water**
- **Partner Roles**
 - Bench-Scale Studies (AwwaRF)
 - Demonstration Studies (Sandia)
 - Economic Analysis/Outreach (WERC)
- **Focus on small systems**
 - 40% of resources directed to rural and Native American utility needs
 - Minimize costs - capital, operating, maintenance
 - Minimize residual quantities & disposal costs





Sandia Pilot Test Concepts

- **Side-by-side demonstrations of technologies tested by AwwaRF bench-scale program, WERC design contest, or commercial technologies vetted through Vendor Forums**
 - Test duration: 3 – 9 months
 - Test size: 0.3 – 10 gpm
 - Different technology classes: adsorptive media, Coagulation/Filtration, membranes, electrochemical
- **Cooperative effort between Sandia, Technology Owner and Site Owner**
- **Test Protocols developed with help from NSF International, academia, industry during 2004-2005**

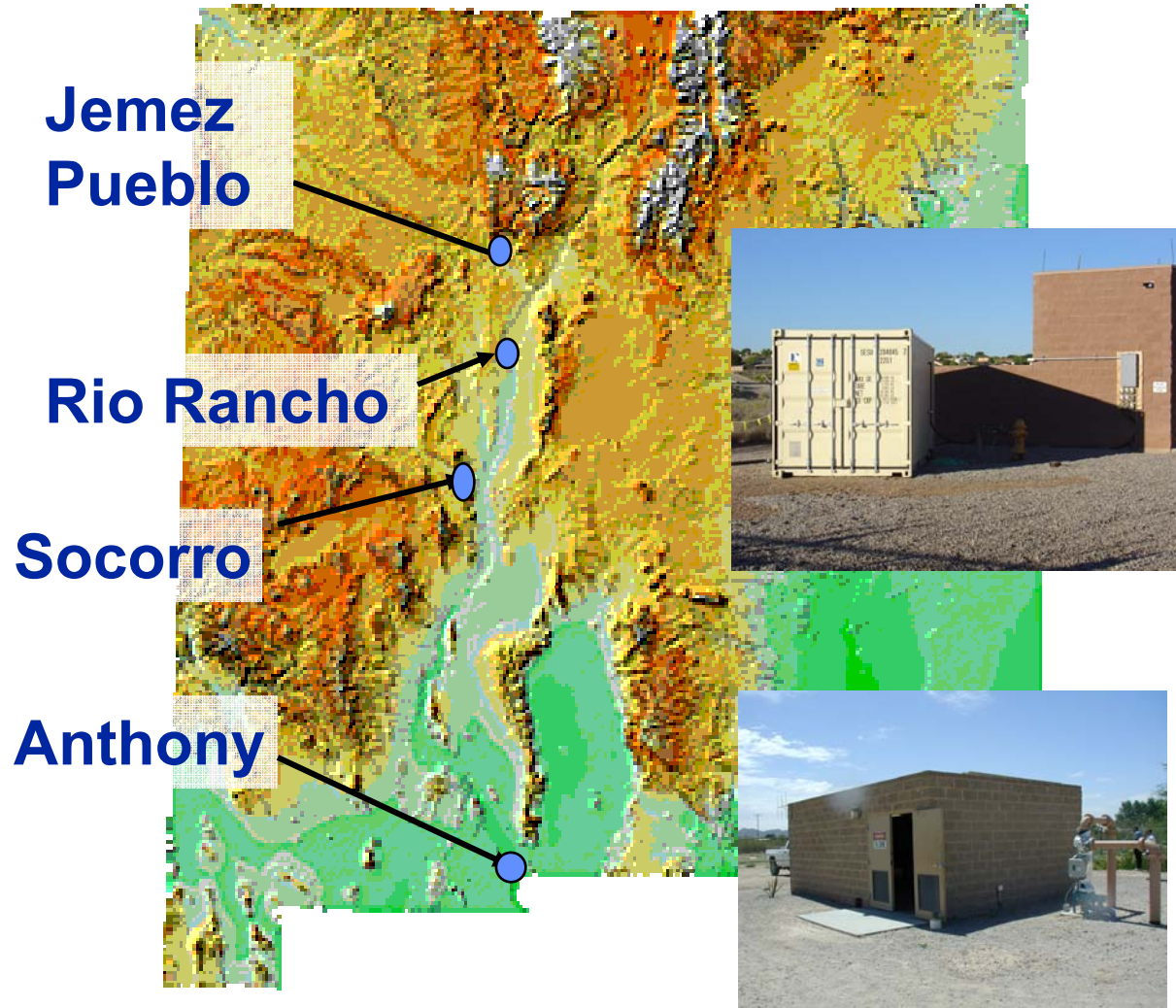


Things we look for in a pilot site

- **As concentration (>10 ppb)**
- **Example ground water composition that will help other communities**
 - pH, TDS, foulants such as Fe, Mn, silica, and organics
 - As(III)/As(V)
 - Competing ions (V, SO₄, etc.)
 - Other contaminants of concern/benefit (e.g, Ra, U, ClO₄, F)
- **Small size of system to be treated (< 10,000 users)**
- **Community support facilitates rapid deployment**
 - Water utility
 - Municipal government
- **Ability to deal with residuals/treated effluent**
- **Rural and Native American communities that would benefit from assistance**



Sites in New Mexico





New Mexico Pilot Sites – Water Quality Summary (Average Values)

	Socorro	Anthony	Rio Rancho	Jemez Pueblo
Total As/As(III), ppb	42 / <2	20 / 18	19 / < 1	20 / 19
V (ppb)	11	2	15	<1
SiO ₂ (ppm)	25	37	27	50
SO ₄ (ppm)	29	180	100	24
Ca (ppm CaCO ₃)	44	70	55	155
Fe (ppm)	0.04	0.5	0.15	1.2
pH	8.0	7.7	7.6	7.5
Conductivity (μS/cm)	340	1400	620	770
Alkalinity (ppm CaCO ₃)	130	180	160	290
TOC (ppm)	0.5	0.8	0.5	2.0
NO ₃ (ppm N)	0.2	0.0	2.0	0.0
F (ppm)	0.50	0.50	0.90	1.00

RED = above EPA Primary MCL; **BLUE** = above EPA secondary MCL

First Community Pilot: Socorro, NM

- 100% groundwater source for drinking water
- 2 warm springs (90°F) provide 500 gpm, 35 – 55 ppb As(V) by gravity flow.
- Formerly site of tap for bottled water company;
- Optimal F for oral health
- Phase 1: Feb-Oct 2005
 - Tested
 - Fe oxides: AD33, ARM200
 - Resin - ArseneX^{np}
 - Ti-oxide - Metsorb
 - Zr-oxide - Isolux
 - EBCT study of AD33
 - 3,4,5 min



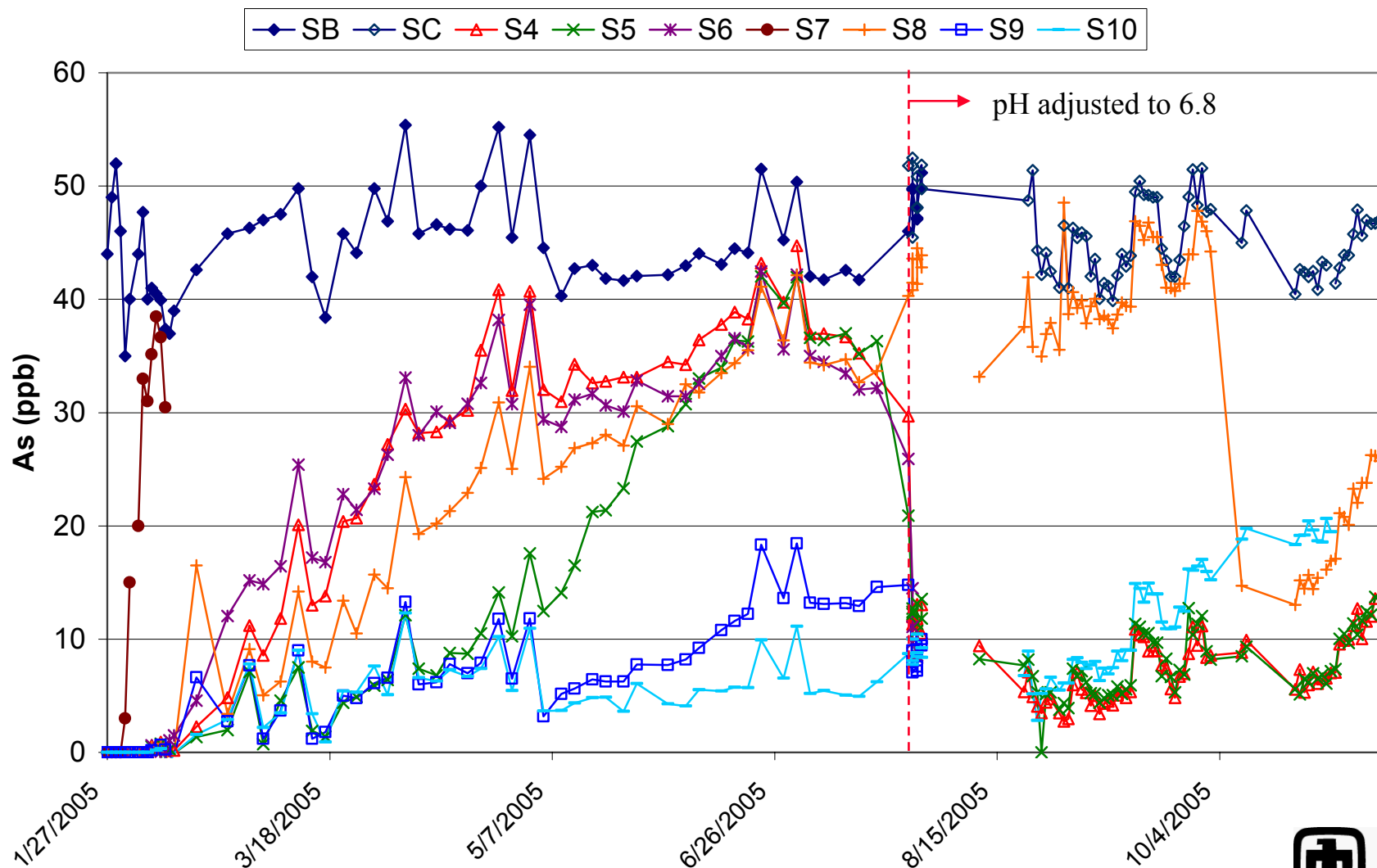


First Community Pilot: Socorro, NM

Vendor Media	MetSorb (S6)	AD-33 (S8-10)			Isolux 302M (S7)	ARM 200 (S4)	ArsenX ^{np} (S5)
HLR, gpm/ft ²	8	6			23	6	8.1
EBCT, min.	2	2	4	5	0.20	4	3
Pre-filtration required?	No	No	No	No	Yes (0.5μm)	No	No
H _{col} , inches	39	39	60	60	10	60	60
H _{media} , inches	25.7	19.3	38.5	48.1	10	38.5	39.2
Media V, L	3	2.2	4.5	5.6	0.39	4.5	4.7
Water FR, gpm	0.4	0.3	0.3	0.3	0.5	0.3	0.4
BW FR, gpm	0.3	0.3			N/A	0.3	0.2

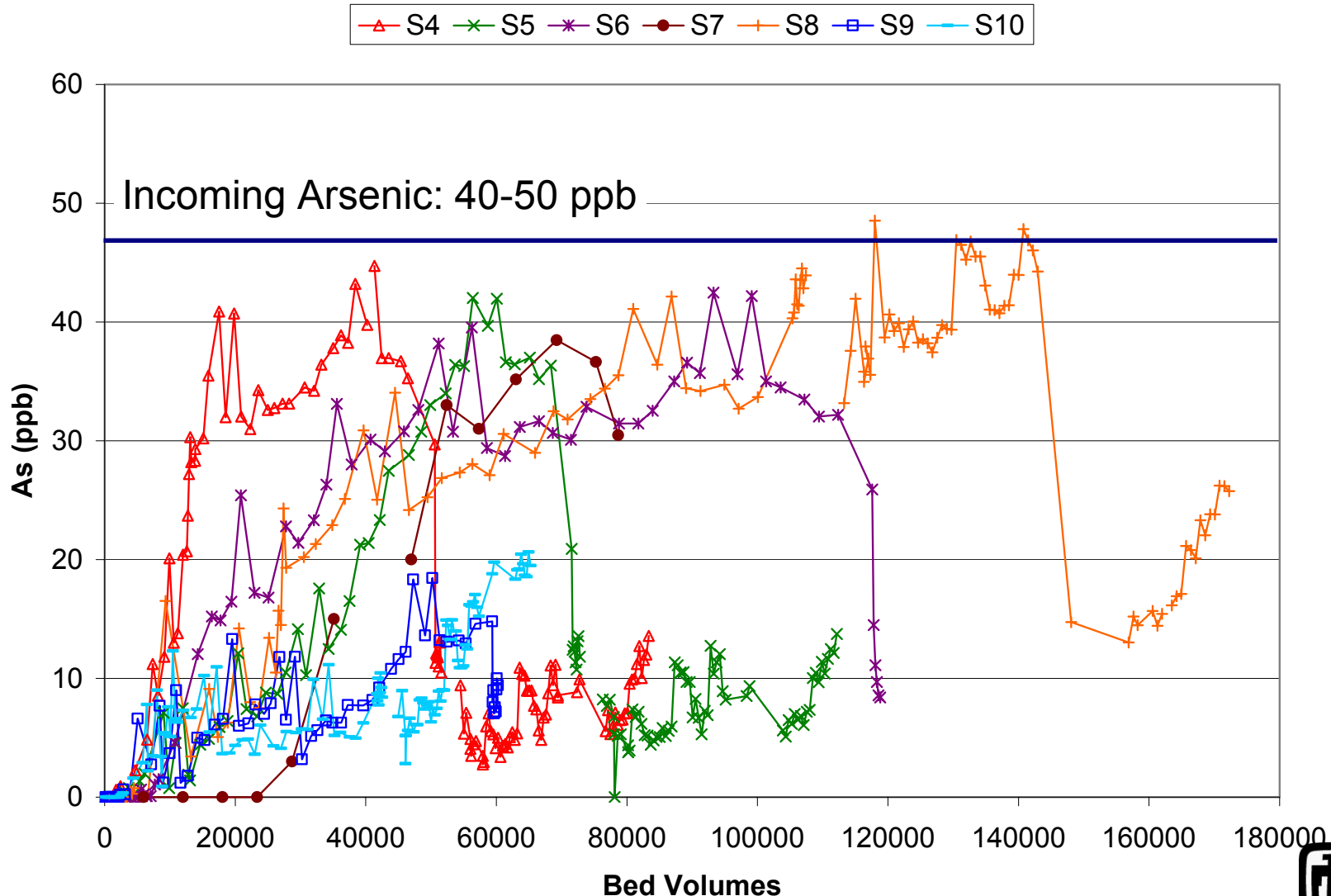
Socorro Pilot Phase I and IIa Events

SB, SC = Influent; S4 = ARM200 (FeOx); S5 = ArseneX^{np} (resin);
S6 = Metsorb (TiOx); S7 = Isolux (ZrOx); S8-10 = AD33 (FeOx)



Media Performance: Socorro, NM

S4 = ARM200 (FeOx); S5 = ArseneXnp (resin); S6 = Metsorb (TiOx);
S7 = Isolux (ZrOx); S8-10 = AD33 (FeOx)





Media Performance in Socorro, NM

• Arsenic Removal Capacity

Parameter	ARM200 (FeOx)	Metsorb (TiOx)	*ArseneX ^{np} (Resin)	Isolux (ZrOx)	AD33 (FeOx)
BV to 10 ppb	8,600	13,000	27,000	32,000	43,000
Capacity at 10 ppb, mg/g	0.60	0.70	1.38	1.67	3.56
Capacity at 35K BV, mg/g	1.17	1.39	1.75	1.67	3.01
Depletion - C/Co at 35K BV	0.88	0.60	0.35	0.38	0.15
BV at C/Co = 0.8	33,000	87,000	53,000	63,000	>270,000
Capacity at C/Co = 0.8	1.15	2.26	2.10	2.23	> 4.62

*ArseneX^{np} batch was defective



Media Performance in Socorro, NM

- Effect of EBCT on Arsenic Removal Capacity

Parameter	AD33		
	2 min	4 min	5 min
BV to 10 ppb	24,000	43,000	42,000
Capacity at 10 ppb, mg/g	1.95	3.56	3.47
Capacity at 35K BV, mg/g	2.59	3.01	2.92
Depletion - C/Co at 35K BV	0.50	0.15	0.12
BV at C/Co = 0.8	84,000	>270,000	>235,000
Capacity at C/Co = 0.8	4.03	> 4.62	>3.47



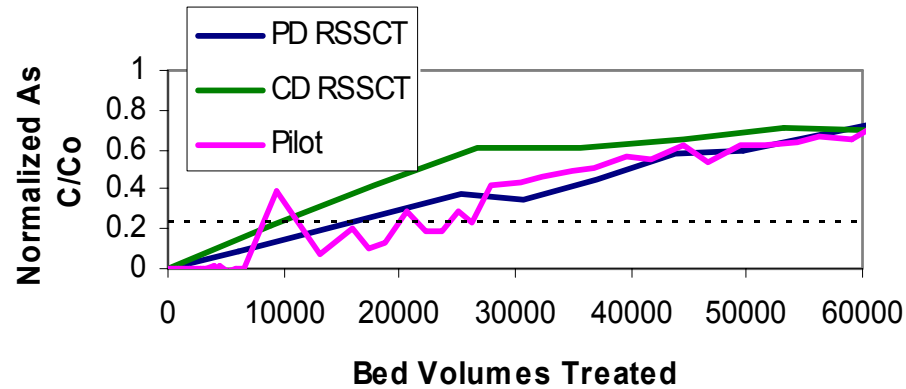
Hydraulic Test Results: Socorro, NM

Results: Physical Observations

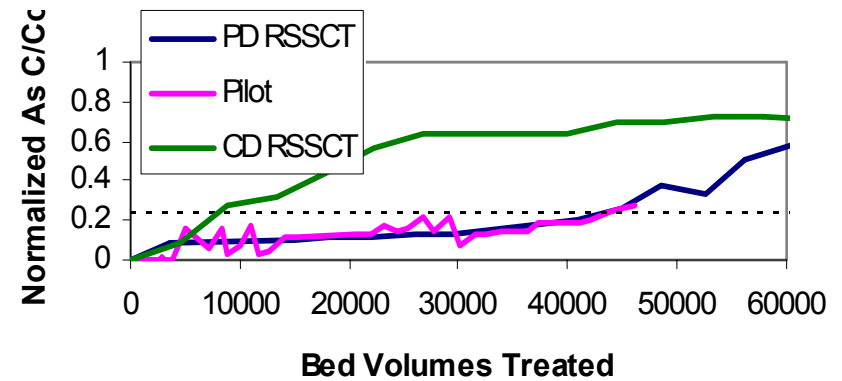
- **Sieve Analysis: 0.8-29% loss**
- **Particle Size Uniformity: All media had $C_u < 5$, most < 2.5 (fairly uniform)**
- **Surface Area: Doesn't seem to control As removal – the media with the smallest surface area had the highest capacity**
- **Each column reacted differently to operating conditions**
 - Media was lost due to backwashing
 - Media compacted throughout pilot experiment

RSSCT Results: Socorro, NM

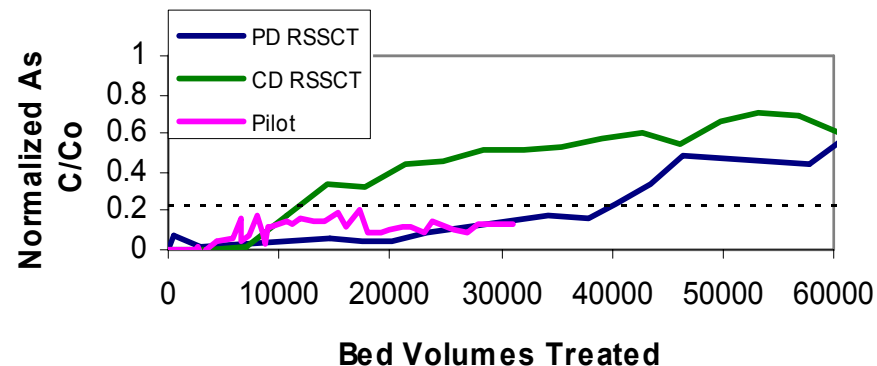
AD33 - 2 min EBCT



AD33- 4 min EBCT

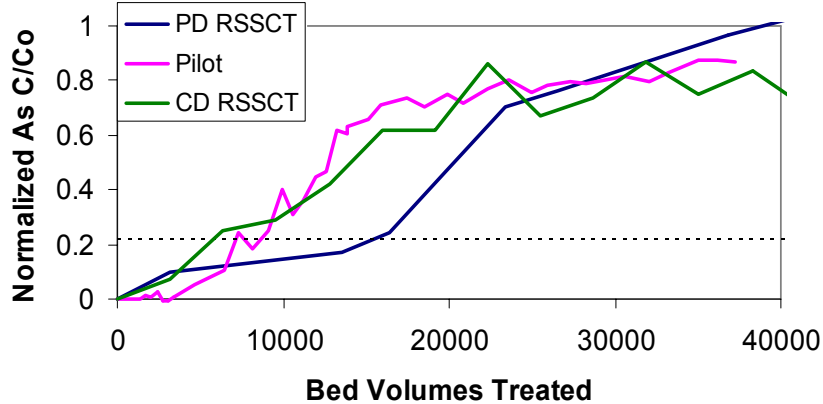


AD33 - 5 min EBCT

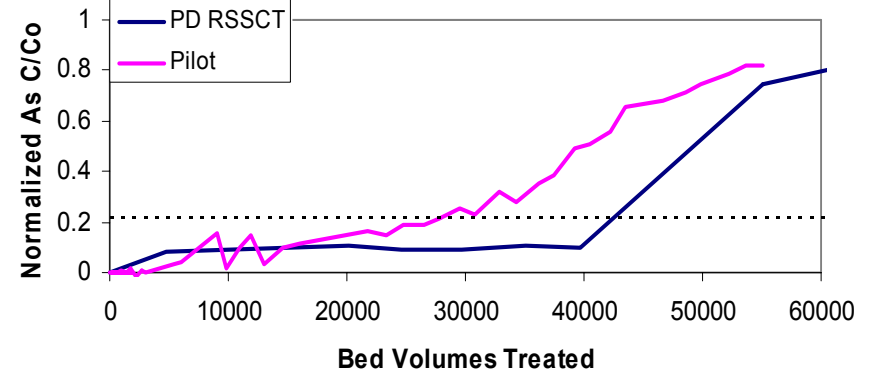


RSSCT Results: Socorro, NM

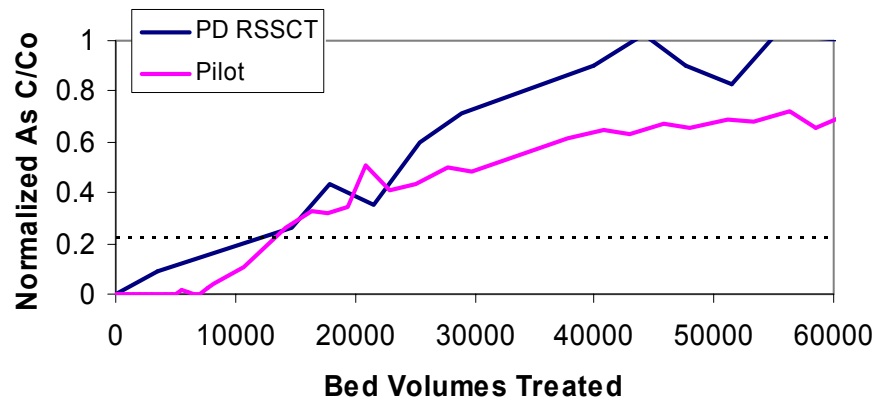
ARM 200



ArseneX^{np}



Metsorb





Objective of RSSCTs

- **Apply RSSCTs to site specific waters to aid in the design of pilot studies and full-scale treatment systems**
- **Significantly reduce time and costs associated with pilot studies**
- **Two RSSCT designs:**
 - **Proportional Diffusivity: duration 2-5 weeks**
 - **Constant Diffusivity: duration 2-10 days**
- **Breakthrough curves from PD and CD RSSCTs should bracket breakthrough curves from pilot columns but so far results are not consistent.**



Phase II Studies in Socorro

Phase IIa:

- **Capacity extension tests of spent media**
 - pH adjustment by CO₂ gas
 - Interrupted flow

Phase IIb:

- **Side-by side comparisons of 5 media at 2 pH levels**
pH = (8: ambient and 6.8:CO₂ gas)
 - ArseneX^{np} – QC'd batches
 - Isolux – larger cartridge for more 'reliable' BV
 - Kemiron – FeOx media
 - SANS – Sandia proprietary media
 - Metsorb – TiOx media
- **Evaluate inadvertent effects of treatment**
 - Loss of pH control and arsenic spike

Second Community Pilot: Anthony, NM (Desert Sands MDWCA)

- 100% groundwater source for drinking water
- Warm springs (~85°F) provide 240-270 gpm, 20 ppb As - mainly As(III).
- High sulfates, TDS
- Intermittent Flow Operation
- Media Tested
 - FeOx: AD33, ARM200, CFH12
 - ZrOx: Isolux
 - TiOx: Metsorb, Adsorbsia GTO
 - Resins: ASM-10HP, ArseneX^{np}
- Phase 2: Coated media December 2005
 - La, Fe, Mg-coated diatomaceous earth
 - FeOx-Coated GAC
 - Fe-coated silicate
 - Also: re-loaded ArseneX^{np} column



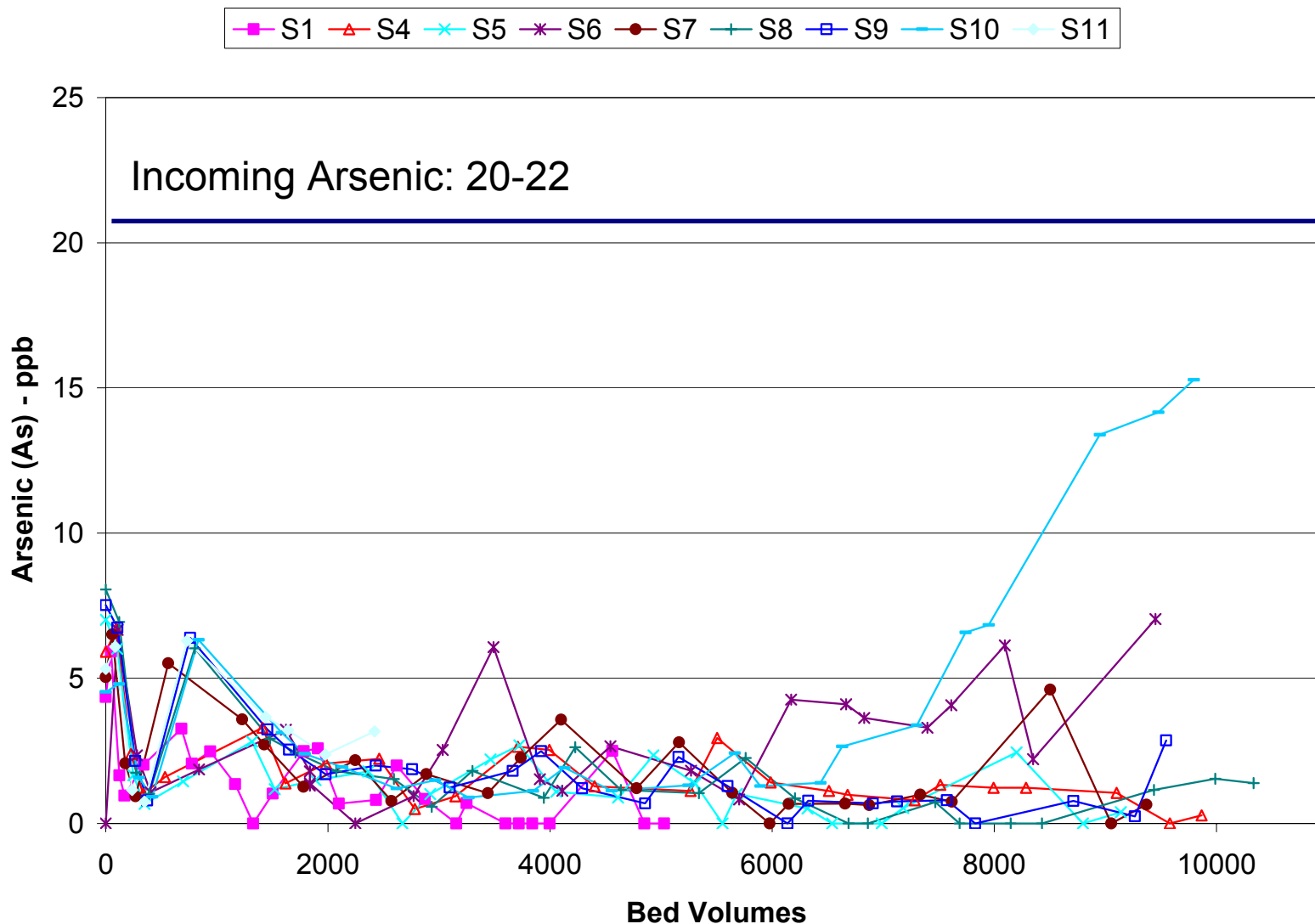
Pilot Scale Design Parameters	Adedge AD33	Kemiron CFH 12	Engelhard ARM 200	Hydroglobe Metsorb	Dow Adsorbsia GTO
Mesh Size	10 x 35	10 x 18	12 x 40	16 x 60	10 x 60
Bulk Density (g/ml)	0.48	0.98	0.76	0.72	0.8
EBCT (min)	3	3	3	3	3
Loading Rate (gpm/ft ²)	6	6	6	6	6
Column Height (in)	50	50	50	50	50
Media Depth (in)	29	29	29	29	29
Media Volume (ft ³)	0.12	0.12	0.12	0.12	0.12
Water Flowrate (gpm)	0.3	0.3	0.3	0.3	0.3

Pilot Scale Design Parameters	MEI Isolux	Purolite ArseneX ^{np}	ResinTech ASM10 HP
Mesh Size	< 400	16 x 50	20 x 40
Bulk Density (g/ml)	0.86	0.81	0.74
EBCT (min)	0.5	3	3
Loading Rate (gpm/ft ²)	Patent pending radial flow cartridge system 42" cartridge height	6	6
Column Diameter (in)		3	3
Media Depth (in)		29	29
Media Volume (ft ³)		0.12	0.12
Water Flowrate (gpm)	0.3	0.3	0.3

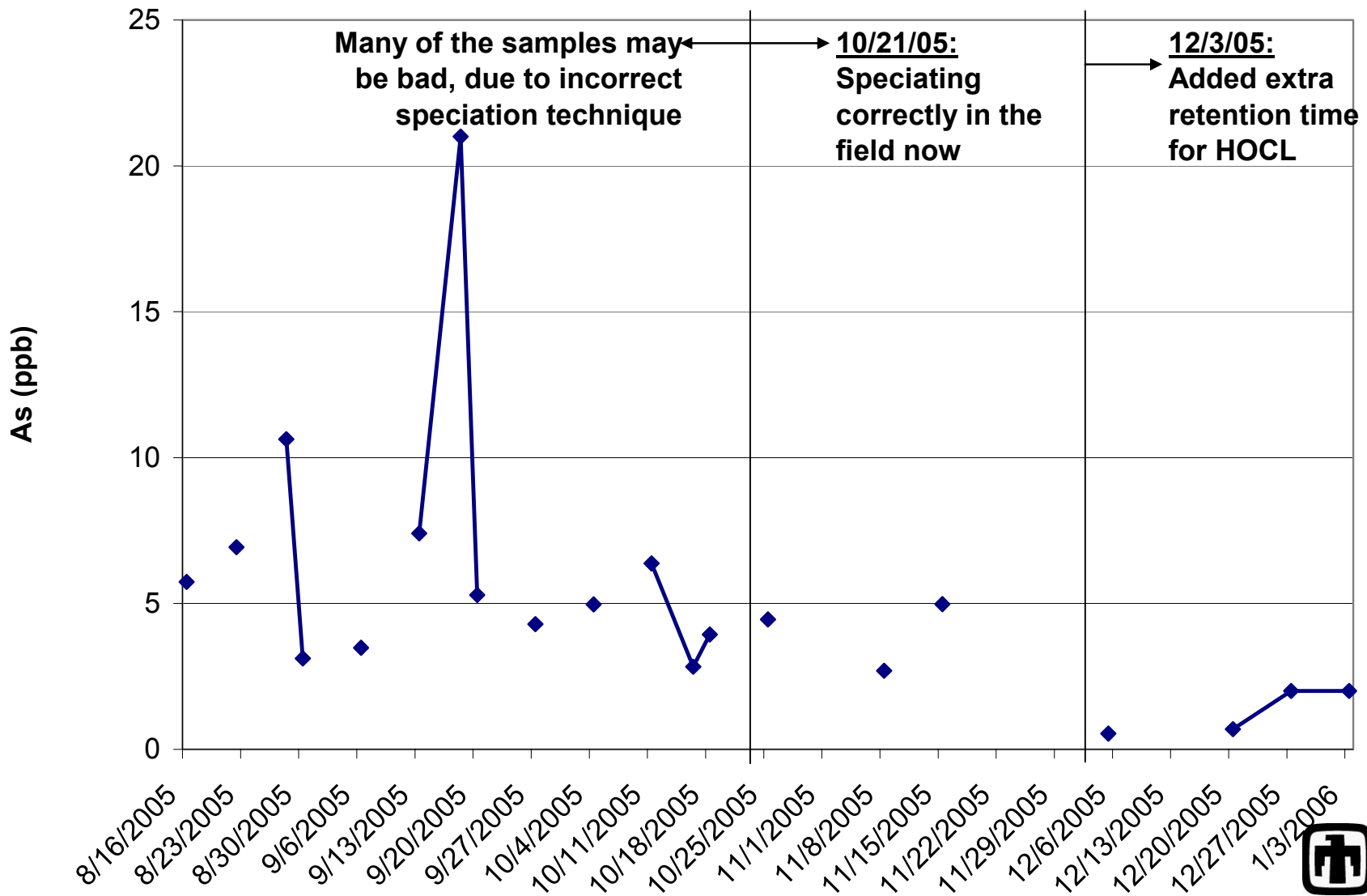


Media Performance: Anthony, NM

S1=Isolux (ZrOx); S4 = CFH12 (FeOx); S5 =AD33 (FeOx); S6 = ARM200 (FeOx);
S7=Adsorbsia GTO (TiOx); S8=Metsorb (TiOx); S9=ArseneX^{np}; S11=NXT-2



Speciation of Arsenic: Anthony, NM



Media Performance: Anthony, NM

- Backwashing:
 - Some media have required monthly backwashing (~2,000 bed volumes)
 - Others have required bi-monthly backwashing (~4,000 bed volumes)
 - A few have required little or no backwashing
- Most media haven't compressed much (compressed < 10% of original height)
- Can see iron oxide forming at top of ZrOx media and pre-filter



Third Community Pilot: Rio Rancho, NM

- 100% groundwater source for drinking water
- Deep well (800 ft) provides 2000 gpm, 20 ppb As (mainly As V).
- High sulfates, Vanadium, TDS
- Phase 1: September 2005 Start
 - FeOx: AD33, CFH10
 - ZrOx: Isolux
 - TiOx: Adsorbsia GTO
 - Resins: ASM-10HP, ARseneX^{np}
- Continuous Flow Operation
- Pre-sieved media prior to loading & initial backwash (> 60 mesh)



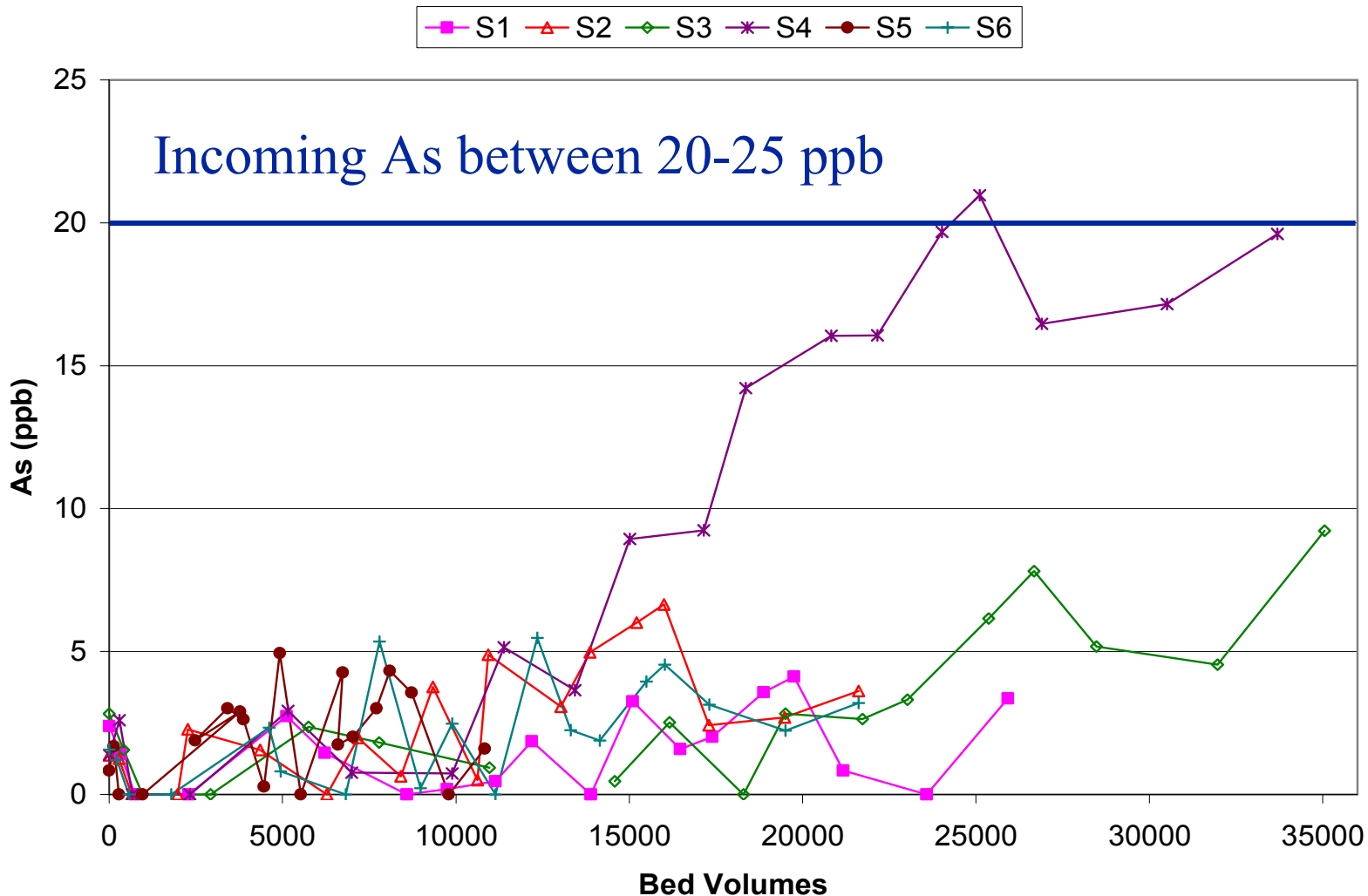


Third Community Pilot: Rio Rancho, NM

Pilot Scale Design Parameters	Adedge AD33	Dow Adsorbsia	Kemiron CFH 10	MEI Isolux	Purolite ArseneX ^{np}	ResinTech ASM10 HP
Mesh Size	10 x 35	10 x 60	10 x 18	< 400	16 x 50	20 x 40
Bulk Density (g/ml)	0.48	0.8	0.98	0.86	0.81	0.74
EBCT (min)	3	3	3	0.5	3	3
HLR (gpm/ft ²)	6	6	6	Patent pending radial flow cartridge system 42" cartridge height	6	6
Media Depth (in)	29	29	29		29	29
Media V (ft ³)	0.12	0.12	0.12		0.12	0.12
Water FR (gpm)	0.3	0.3	0.3	0.3	0.3	0.3
Backwash FR (gpm)	0.4	0.4	0.4	0.4	0.4	0.4

Media Performance: Rio Rancho, NM

S1=AD33 (FeOx); S2 = CFH10 (FeOx); S3 =ArseneX^{np}; S4 = ASM-10HP;
S5=Adsorbsia GTO (TiOx); S6=Isolux (ZrOx)





Summary: Bed Volume Results

Media	Socorro BV to 10 ppb breakthrough	Desert Sands BV to 10 ppb breakthrough ^a	Rio Rancho BV to 10 ppb breakthrough ^b
ARM200	9,000	>10,000	>20,000
AD33	26,000/43,000/42,000 (2/4/5 min EBCT)	>10,000	N/A
CFH12, CFH10	N/A	>10,000	>20,000
Isolux	32,000	>10,000	>20,000
Metsorb	13,000	>10,000	N/A
Adsorbsia GTO	N/A	>10,000	>20,000
ArseneX ^{np}	27,000	>10,000	>20,000
ASM-10HP	N/A	8,000	17,000
NXT-2	N/A	<i>Media broke down at 2,400</i>	N/A

^aPhase 1 not yet complete

^bPhase 1 completion data



Summary: Results

- **Pilot studies have been completed or are in progress at three sites in New Mexico: Socorro, Anthony, and Rio Rancho.**
- **In general, the smaller the particle size of the media, the more susceptible the media is to incoming iron and/or particulate matter.**
 - **These media require more backwashing than others.**
- **Empty bed contact time (EBCT) does have an affect on the relative performance of the media.**
 - **Most media vendors recommend 3-5 minutes EBCT**
 - **3 minute EBCT is generally sufficient, in that higher bed volumes to 10 ppb breakthrough are demonstrated regularly.**



Summary: Future Plans

- In 2006, the Arsenic Water Technology Partnership will undertake several activities:
 - Rio Rancho will be restarted by early spring 2006; a new pilot will also occur at this site
 - Phase 2 operations will begin at the Socorro site
 - A new pilot will start in Oklahoma
 - A new pilot will start at the Jemez Pueblo
- The Jemez Pueblo pilot demonstration site will :
 - Test Coagulation-filtration technologies
 - Test the effectiveness of various oxidizers for Arsenic (III)
 - Compare pilot scale data to full scale iron and manganese removal plant.
- Pilot-specific economic analyses will be performed at each site to gain further insight to the relative performance of each of the media. These results will be used to supplement our partner, WERC, in their efforts to build the Comprehensive Arsenic Tool (CoAsT).



For More Information:

Arsenic Partnership Website

<http://www.arsenicpartners.org/>

Sandia Website

<http://www.sandia.gov/water/arsenic>

WERC CoAsT Website

<http://wercstation.nmsu.edu:8080/arsenic/AsTree.dsb>